

This is what was at the top of Doug Norman's HCP paper submission by way of introduction...

Leptoquarks are hypothetical exotic particles with both lepton and color quantum numbers; they are color triplet bosons with fractional charge. They are produced in pairs at hadron colliders via strong interactions. A leptoquark will decay via an unknown coupling, λ , to a lepton and a quark. The production of leptoquark pairs in $p\bar{p}$ collisions is insensitive to λ , and we are not concerned with this coupling as long as it is greater than 10^{-12} ; otherwise, the leptoquarks will not decay in our detector and escape detection. We assume that leptoquarks occur in generations; this is to say that leptoquarks of one generation couple exclusively to leptons and quarks of the same generation. For example, a first generation leptoquark will only couple to electrons, electron neutrinos and u or d quarks. With this assumption of generations, we are able to bypass strict bounds (≥ 1 TeV) on leptoquark masses derived from limits on flavor changing neutral currents.

Since leptoquarks are produced dominantly in pairs at hadron colliders, their signature would be two leptons plus two or more jets. A free parameter of the model for leptoquarks is the branching fraction of the leptoquark to charged lepton plus quark, β . For $\beta = 1.0$, leptoquarks decay 100% to a charged lepton plus quark. In the case for a first generation leptoquark pair, the signature would be two isolated electrons (e^+e^-) plus at least two jets. Additional jets could arise from initial state radiation or final state radiation. Since we assume leptoquarks do not couple outside their own generation, for first generation leptoquarks, we would not expect to see muons or evidence of taus in the signature.

Now, onto the section I'm adding...

1 First Generation Leptoquarks

DØ searches for high mass first generation leptoquarks primarily in the dielectron plus two jets. This is an especially exciting topic of recent as this is one possible interpretation of the high mass events seen at HERA [1]. The data sample used in this analysis is the full Run I data sample of 123 pb^{-1} .

The basic $eejj$ event selection is given in the following list:

- two electrons with $E_T > 20 \text{ GeV}$ with in the central calorimeter
- two central jets with $E_T > 15 \text{ GeV}$ with $|\eta| < 2.5$
- exclude events with dielectron invariant masses between 82 to 100 GeV/c^2 (3σ about the Z mass).

With this basic selection, we have 101 events in our candidate sample. The main backgrounds come from Drell-Yan, QCD with jets faking electrons, and Top. We estimate 66.8 ± 13.4 events for Drell-Yan, 24.3 ± 3.6 events from QCD, and 1.8 ± 0.7 events from Top for a total of 92.8 ± 13.8 background events.

Further event selection is optimized for leptoquark masses of $200 \text{ GeV}/c^2$ and greater. The optimization is based on signal and background Monte Carlo event samples and on a QCD data event sample. Using advanced techniques such as neural nets and grid searches we studied several variables before settling on a transverse energy variable, $S_T = \sum_{\text{jets}} E_T^j + E_T^{e1} + E_T^{e2}$.

Optimizing shows the cut $S_T > 350 \text{ GeV}$ is optimal for setting a high mass limit. The expected background after the S_T cut is applied is 0.4 events; none of the 101 data events survive the cut.

We have also studied the mass properties of the 101 dielectron candidate event sample. We used a 3C (3 constraint) fit where we require balance of the transverse energy in the event and we require the masses of the two reconstructed electron-jet systems be equal. The mass fitter is based on SQUAW, an old bubble chamber mass fit program, modified by Rich Partridge and Gordon Watts. The electron-jet combination that has the lowest fit χ^2 is chosen. The 3C mass fit for a $225 \text{ GeV}/c^2$ mass leptoquark sample ($\beta = 1.0$) can be seen in Fig 2. The peak of the distribution is about 10% low but the mass resolution is good at about $15 \text{ GeV}/c^2$.

In Fig. 3 a)-c) we show the fit mass for the background, LQ $225 \text{ GeV}/c^2$ signal, and data as a function of both the fit mass and S_T . The area of the

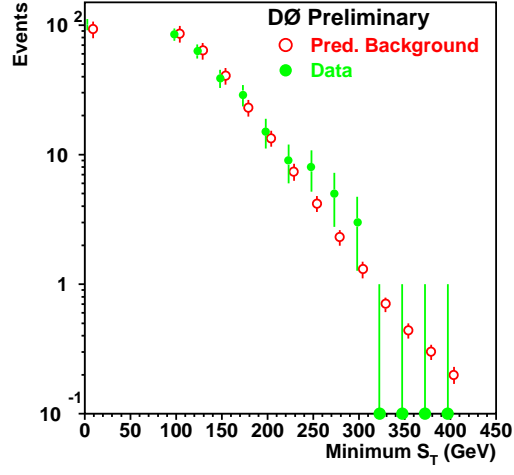


Figure 1: The integrated distribution of S_T for data and background predictions. The basic event selection is applied.

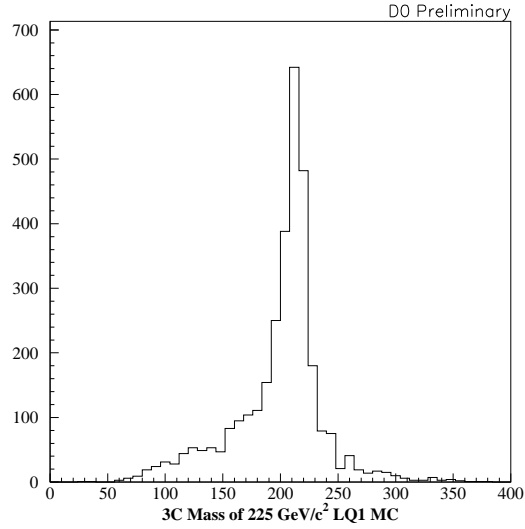


Figure 2: The 3C mass fit for a 225 GeV/c² mass leptoquark sample, $\beta = 1.0$.

box plots is normalized to the number of events expected or observed in the data sample. Fig. 3 d) shows a projection of all three plots along the fit mass axis for both the full 101 events and a sample with an $S_T > 250$ GeV cut. The points are data, the solid line is the calculated background, and the dashed line is LQ 225 GeV/c² Monte Carlo. Note that the two high mass data events, having a fit mass close to 260 GeV/c² can be seen in Fig. 3c) to have low S_T . Indeed, the inset of d) shows the events are removed when a $S_T > 250$ GeV cut is applied. Clearly, the data looks very much like the background.

Given that we see no dielectron leptoquark signal in our data, we can proceed to set a limit on the production cross section for leptoquark pairs, and by comparing to theory we can set limits on the leptoquark mass. The systematic errors for detecting the $eejj$ events are listed here:

| | |
|---|------|
| energy scale: | 2-5% |
| electron identification: | 5% |
| acceptance: | 5% |
| gluon radiation: | 7% |
| parton distribution functions and Q^2 : | 7% |
| luminosity: | 5% |
| Monte Carlo statistics: | 2% |

Given the efficiency and uncertainties, we calculate [2] a 95% CL limit on the production cross section times β^2 as a function of leptoquark mass, shown in Fig. 4. Also given is the NLO theoretical prediction. The band represents the range in cross section prediction as the renormalization scale changes from one half the leptoquark mass (upper boundary: $\mu^2 = 1/4 \times M_{LQ}^2$) to twice the leptoquark mass (lower boundary: $\mu^2 = 4 \times M_{LQ}^2$). The intersection of our experimental limit on the cross section and the lower boundary of the theory prediction gives a 95% CL limit of 225 GeV/c² on the mass of the leptoquark for $\beta = 1.0$.

References

- [1] C. Adloff *et al.* (H1 Collaboration), DESY-97-024, Feb. 1997, hep-ex/9702012, submitted to Z. Phys. C; J. Breitweg *et al.* (ZEUS Collaboration), DESY-97-025, Feb. 1997, hep-ex/9702015, submitted to Z. Phys. C.

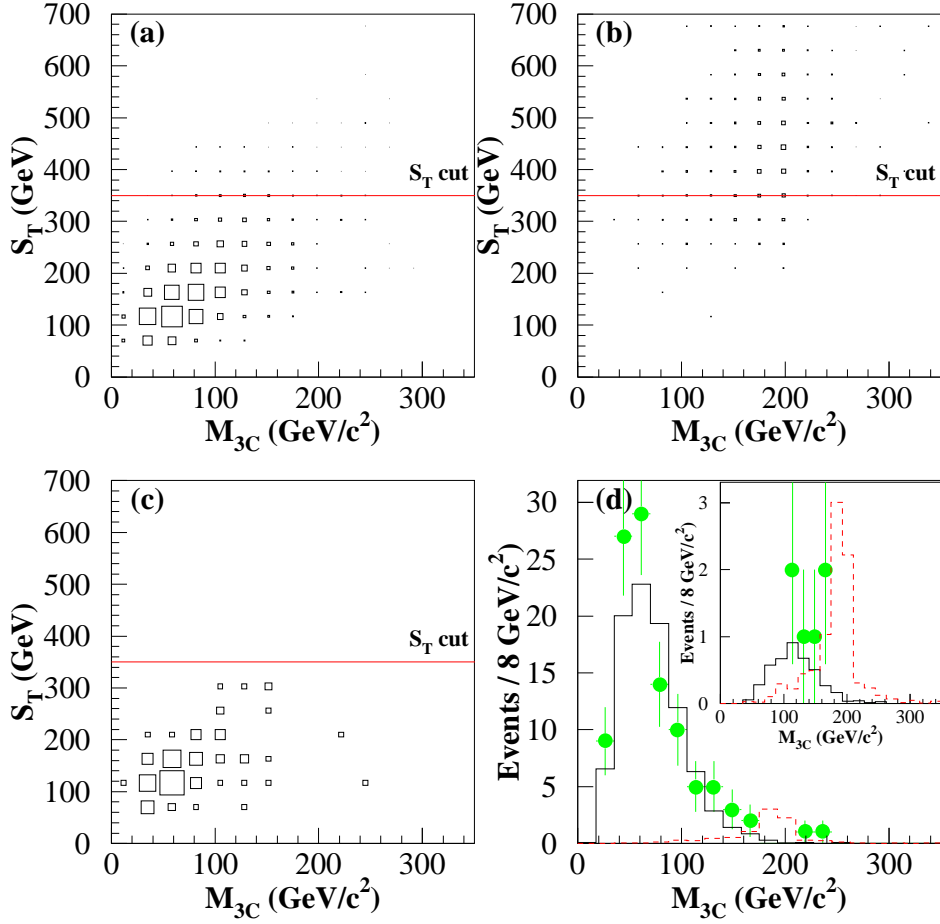


Figure 3: The expected background is shown in a), the expected LQ signal for a leptokuark mass of 200 GeV/c² is shown in b), and the data is shown in c) as a function of both S_T and the 3C fit mass. The area of the boxes is normalized to the number of events expected in each bin for the 123 pb⁻¹. All three plots are projected onto the 3C fit mass axis in d). The points are the data, with statistical error bars, the solid histogram is the background, and the dashed plot is the expected 200 GeV/c² signal. All 101 events are shown in the plot; the inset has a further requirement of $S_T > 250$ GeV applied.

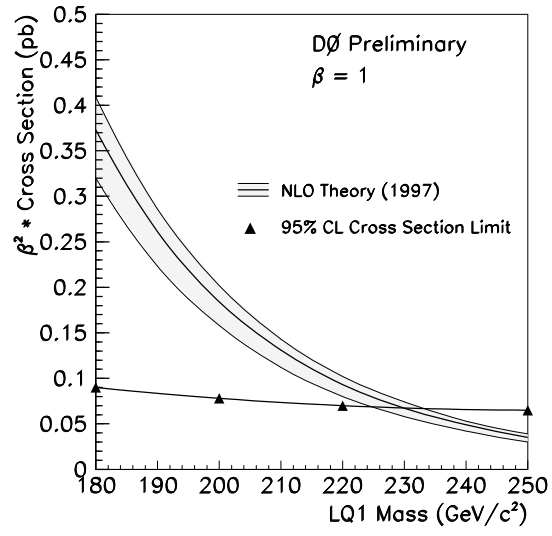


Figure 4: The 95% CL limit on the production cross section times β^2 . Also shown as the band is the NLO theoretical prediction [3].

- [2] I. Bertram *et al.*, *A Recipe for the Construction of Confidence Limits*. D0NOTE 2775A, 1995, unpublished.
- [3] NLO theory: Krämer, Plehn, Spira, and Zerwas, hep-ph/9704322 (1997).